AP® PHYSICS B
2013 SCORING GUIDELINES

Question 4

10 points total **Distribution of points**

(a) 3 points

For using a correct expression for the vertical motion to determine time t 1 point

$\Delta y = v_{yi}t + \frac{1}{2}at^2$

$v_{yi} = 0$, so $t = \sqrt{\frac{2(\Delta y)}{a}}$

For substituting the correct height and acceleration into the vertical equation 1 point

$t = \sqrt{\frac{(2)(2.4\text{ m})}{(9.8\text{ m/s}^2)}} = 0.70\text{ s}$

For substituting the correct values into the constant horizontal velocity equation 1 point

$v_x = \frac{\Delta x}{t}$

$v_x = \frac{(1.8\text{ m})}{(0.70\text{ s})} = 2.6\text{ m/s}$

(b) 2 points

For using a correct expression to determine the acceleration of the block 1 point

$v_x^2 = v_0^2 + 2ad$

$a = \frac{v_x^2}{2d}$

For correct substitutions consistent with part (a) 1 point

$a = \frac{(2.6\text{ m/s})^2}{(2)(0.95\text{ m})} = 3.5\text{ m/s}^2$

Question 4 (continued)

Distribution of points

(c) 3 points

For using Newton's second law
$\sum F = ma$
$m_{obj}g = \left(m_{obj} + M + m_{ball}\right)a$

For a correct value for the total force on the system — 1 point
$m_{obj}g = (2.5\ \text{kg})\left(9.8\ \text{m/s}^2\right) = 25\ \text{N}$

For correct values in the expression for the total mass being accelerated — 1 point
$\left(m_{obj} + M + m_{ball}\right)a = (2.5\ \text{kg} + 0.3\ \text{kg} + M)a = (2.8\ \text{kg} + M)a$

For the correct substitution of the acceleration of the block from part (b) — 1 point
$25\ \text{N} = (2.8\ \text{kg} + M)\left(3.5\ \text{m/s}^2\right)$
$M = 4.24\ \text{kg}$

(d) 2 points

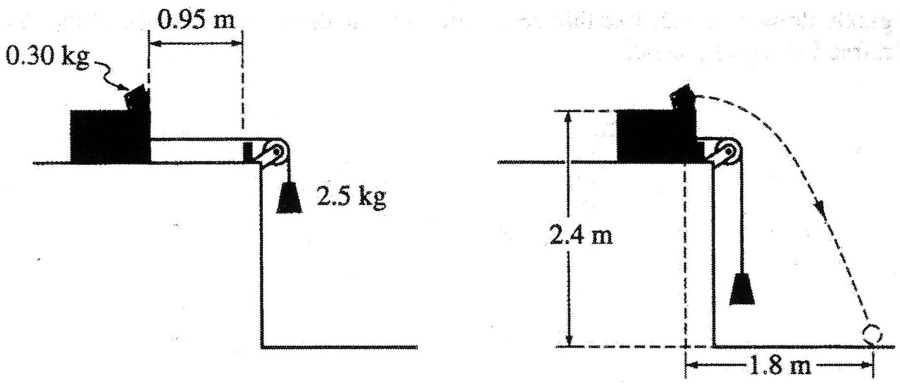
For stating that with the same force, the horizontal acceleration of the ball will be less as a result of the increased mass of the system — 1 point

For stating the launch velocity will be lower — 1 point

Example

A larger combined mass of the system will result in a smaller acceleration, so the ball has a smaller speed upon launch. However, the time to hit the floor will be the same since it's falling the same vertical distance with the same vertical acceleration in freefall. So the horizontal distance $\left(v_{launch} \times t_{fall}\right)$ will be less.

One earned point was deducted for any incorrect statement in the reasoning not included in the points shown.



4. (10 points)

A 0.30 kg ball is in a cup of negligible mass attached to a block of mass M that is on a table. A string passing over a light pulley connects the block to a 2.5 kg object, as shown above. The system is released from rest, the block accelerates to the right, and after moving 0.95 m the block collides with a bumper near the end of the table. The ball continues to move and lands on the floor at a position 2.4 m below and 1.8 m horizontally from where it leaves the cup. Assume all friction is negligible.

(a) Calculate the speed of the ball just after the block hits the bumper and the ball leaves the cup.

x	y
$v_x = ?$	$v_y = 0$
$d = 1.8$ m	$a = -9.8$
$a = 0$	$d = 2.4$ m
$t = .6995$ s $= ?$	

$d = v_0 t + \frac{1}{2} a t^2$

$\frac{2(2.4)}{9.8} = t^2$ $\quad t = .6995$

$d = v_x t + \frac{1}{2} a t^2$

$\frac{1.8}{.6995} = v_x$ $\quad v_x = 2.57 \text{ m/s}$

(b) Calculate the magnitude of the acceleration of the block as it moves across the table.

$v^2 = v_0^2 + 2ad$

$\frac{v^2}{2d} = \frac{2ad}{2d}$

$a = \frac{2.57^2}{2(.95)}$ $\quad a = 3.48 \text{ m/s}^2$

(c) Calculate the mass M of the block.

$\Sigma F = ma$

$2.5(9.8) = (.3 + 2.5 + M)\, 3.48$

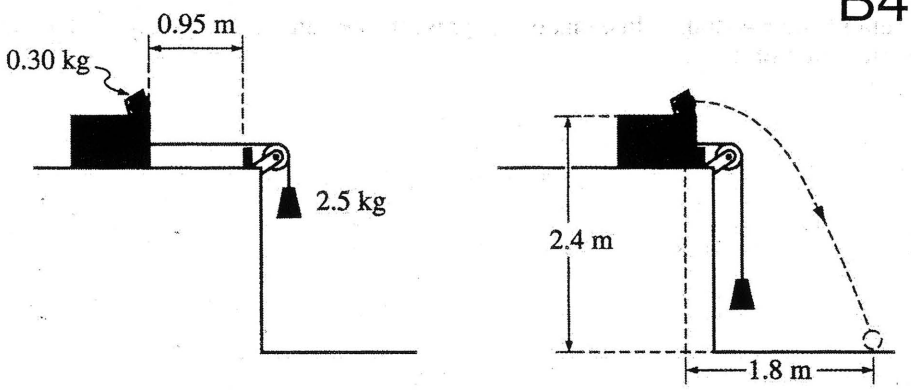
$7.037 = .3 + 2.5 + M$

$M = 4.24\text{kg}$

(d) If the mass of the ball is increased, the horizontal distance it travels before hitting the floor will decrease. Explain why this will happen.

If you increase the mass of the ball the total mass of the system will increase which would decrease the acceleration because the force applied remains the same. Because the acceleration decreases the velocity of the ball when it hits the bumper will also decrease. this will decrease the distance it travels before hitting the floor.

B4 B1



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(a) Calculate the speed of the ball just after the block hits the bumper and the ball leaves the cup.

$v^2 = v_0^2 + 2a(y - y_0)$

$v^2 = 0 + 2(9.8\ m/s^2)(.95m - 2.4m)$

$v = \sqrt{28.42}$

$v = 5.33\ m/s$

$v = v_0 + at$

$5.33\ m/s = 0 + 9.8\ m/s(t)$

$t = .54s$

$v = \frac{d}{t}$

$v = \frac{.95m}{.54s}$

$v = 1.78\ m/s$

(b) Calculate the magnitude of the acceleration of the block as it moves across the table.

$v = v_0 + at$

$1.78\ m/s = 0\ m/s + a(.54s)$

$a = 3.3\ m/s^2$

(c) Calculate the mass M of the block.

$F_T \leftarrow 2.5kg(9.8 m/s^2)$

$F = ma$

$24.5N = (.30kg + M)(3.3 m/s^2)$

$7.42 = .30kg + M$

$7.12kg = M$

(d) If the mass of the ball is increased, the horizontal distance it travels before hitting the floor will decrease. Explain why this will happen.

This will happen because with more mass the objects final velocity upon release will be less than when it started and with less initial horizontal velocity the projectile will not travel as far.

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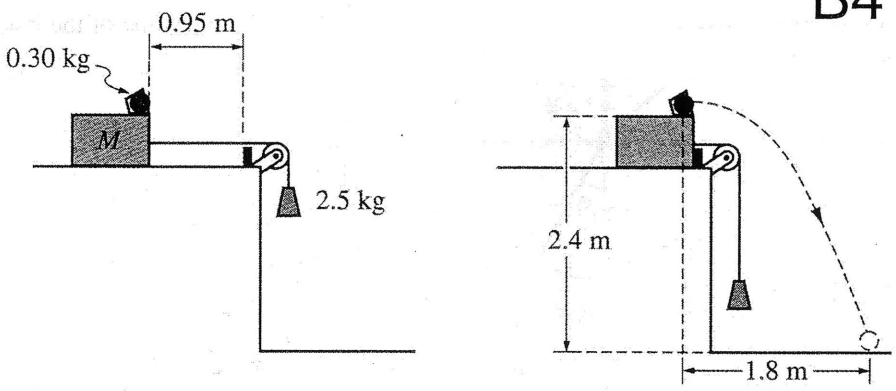

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(a) Calculate the speed of the ball just after the block hits the bumper and the ball leaves the cup.

X	Y
$a = 0$	$a = -10$
$\Delta x = 1.8$	$\Delta y = 2.4$
$t = .693$	$V_i = 0$
$V_i = ?$	$t = ?$

$\Delta y = \cancel{V_i t}^{0} + \frac{1}{2} a t^2$

$2.4 = \frac{1}{2}(10) t^2$

$.48 = t^2$

$t = .693$

$\Delta x = V_i t + \cancel{\frac{1}{2} a t^2}^{0}$

$1.8 = V_i (.693)$

$V_i = 2.598 \text{ m/s}$

(b) Calculate the magnitude of the acceleration of the block as it moves across the table.

$\Sigma F = ma$

$F_{app} = ma$

B4 C2

(c) Calculate the mass M of the block.

$KE = PE$

$\frac{1}{2}mv^2 = mgh$

(d) If the mass of the ball is increased, the horizontal distance it travels before hitting the floor will decrease. Explain why this will happen.

Because the ball will have to travel the same speed while carrying more weight so it travels a smaller distance. If the speed increased, then the ball would be able to travel a farther distance.

AP® PHYSICS B
2013 SCORING COMMENTARY

Question 4

Overview

This question assessed students' understanding of one- and two-dimensional kinematics as well as Newton's first and second laws.

Sample: B4-A
Score: 10

This response is an example of an outstanding solution. The equations were written out, then substitutions inserted and the answer was easy to find. Part (a) uses both horizontal and vertical motion to correctly determine the speed of the ball. Part (b) uses a kinematics equation to get the acceleration. Part (c) is a well-organized use of Newton's second law on the system to determine the unknown mass. The writing in part (d) is sequential and clear.

Sample: B4-B
Score: 6

The first point in part (a) was earned for using the correct kinematic equations. The incorrect distance substitutions for both the vertical and horizontal equations did not earn the next possible 2 points. Full credit was earned in part (b) for substitutions consistent with part (a) into the correct equation. Part (c) lost 1 of the 3 points for not including the mass of the hanging object (i.e., the sum of the masses) in the calculation. One point was lost in part (d) by not discussing why the acceleration was less.

Sample: B4-C
Score: 3

Full credit was earned in part (a). Part (b) could not be solved using Newton's second law and no credit was earned for the incorrect approach. Part (c) could be solved with the energy equation shown, but needed the correct substitutions to earn any of the 3 points. The argument used in part (d) was in a negative form and had no force reasoning, so no credit was earned.